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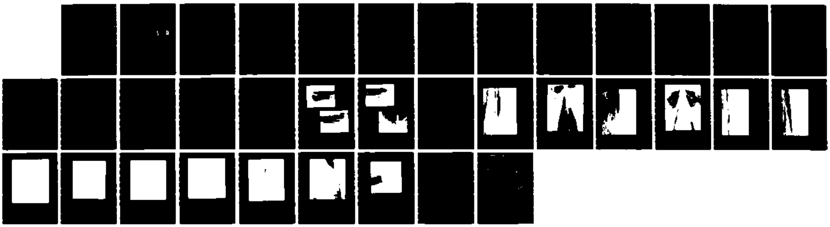

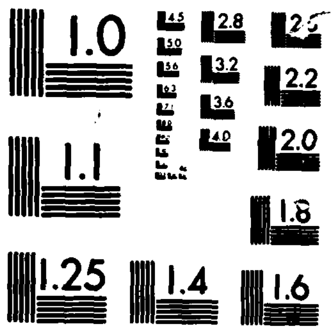

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DAVID W. TAYLOR NAVAL SHIP RESEARCH AND DEVELOPMENT CENTER

Bethesda, Maryland 20084

AD-A167 736

FLOW VISUALIZATION EXPERIMENTS ON WEAPONS RANGE SUPPORT CRAFT (YFRT) AS REPRESENTED BY MODEL 5442

by

Dominic S. Cusanelli

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SHIP PERFORMANCE DEPARTMENT REPORT

NOVEMBER 1985

DTNSRDC/SPD-1140-02

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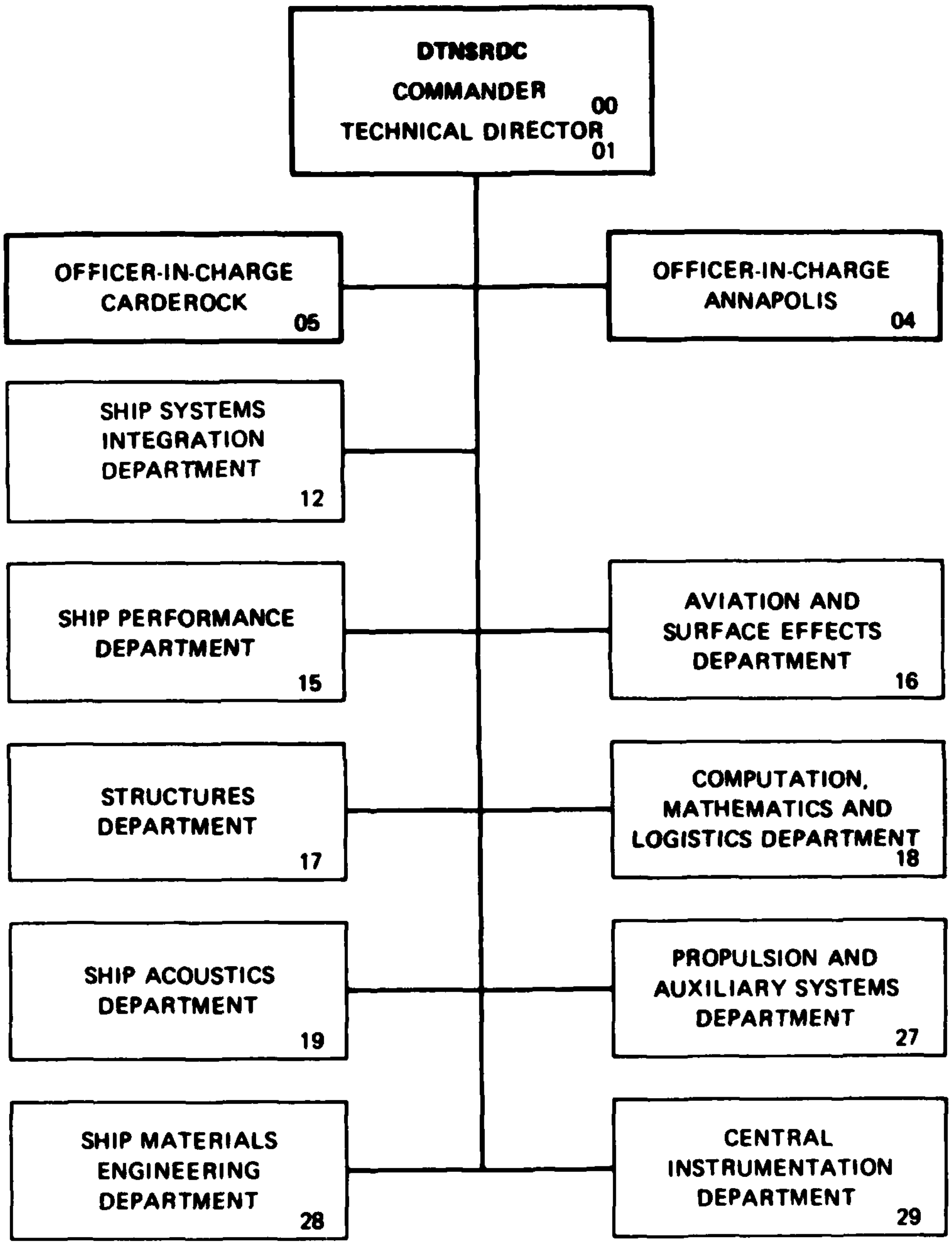
MAJOR DTNSRDC ORGANIZATIONAL COMPONENTS



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Flow visualization experiments were conducted on DTNSRDC Model 5442 representing the 198 foot (60.35 meter) Weapons Range Support Craft (YFRT). Rudder angles for flow separation and incipient rudder ventilation were determined. Flow over the model and appendages was observed for signs of flow separation, and bilge keel alignment was checked.

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NOTATION

All Notation is in accordance with standard ITTC nomenclature as presented in BSRA Technical Memorandum 500, May 1976.

ENGLISH - METRIC CONVERSIONS

1 degree (angle)	= 0.01745 rad (radians)
1 foot	= 0.3048 m (meters)
1 foot per second	= 0.3048 m/sec (meters per second)
1 inch	= 25.40 mm (millimeters)
1 knot	= 0.5144 m/s (meters per second)
1 long ton (2240)	= 1.016 metric tons (1016 Kilograms)
1 horsepower	= 0.746 kW (kilowatts)

ABSTRACT

Flow Visualization experiments were conducted on DTNSRDC Model 5442 representing the 198 foot (60.35 meter) Weapons Range Support Craft YFRT. Rudder angles for flow separation and incipient rudder ventilation were determined. Flow over the model and appendages was observed for signs of flow separation, and bilge keel alignment was checked.

ADMINISTRATIVE INFORMATION

This report was funded by the Naval Sea Systems Command (NAVSEA) under Work Request Number N002485 WR12013, Task Area S180342, Element Number 64567N. The work was performed by the Ship Performance Department of the David Taylor Naval Ship R&D Center (DTNSRDC) under Work Unit Number 1-1521-763.

INTRODUCTION

The Naval Sea System Command (NAVSEA) requested that model experiments be performed at the David Taylor Naval Ship Research and Development Center (DTNSRDC) to assist in the evaluation of the contract design of the 198.0 foot (60.35 meter) Weapons Range Support Craft YFRT. The purpose of the flow visualization experiment is to examine the characteristics of the flow around the hull and the associated appendages, with particular emphasis placed on the stern and areas surrounding the rudders, bilge keels, bow thrusters, and torpedo tubes. The minimum rudder angle for flow separation and the minimum rudder angle for ventilation inception are to be determined.

MODEL DESCRIPTION

DTNSRDC Model Number 5442, built under contract by the University of Michigan, represents the contract design of the 198 foot (60.35 meter) Weapons Range Support Craft, YFRT. The University of Michigan assigned Model Number 1547 to this model, however prior to this series of testing it was designated DTNSRDC Model 5442, and throughout this report will be referred to by this number. The model was built of wood to a linear ratio of 10.232. Figure 1 contains a body plan and principal dimensions of YFRT at design displacement of 1260 tons (1280 tonnes). Figures 2, 3, and 4 reproduced from Reference 1, are drawings of the

hull and appendage configuration on Model 5442 as tested. Appendages included on the model during the experiments were two rudders, torpedo tubes, bow thrusters, bilge keels, a stern wedge, shafting, bossings, and Vee struts. Photographs for the model as equipped for the flow visualization experiments appear in Figures 5 and 6.

For these experiments, the stock propellers chosen to represent full scale fixed pitch propellers for the YFRT were DTNSRDC propellers 4274 and 4275. These propellers represent full scale propellers 6.5 feet (1.98 m) in diameter. with a pitch ratio (P/D) of 1.216. A propeller drawing for these propellers appears in Figure 7.

Station lines (indicated by larger numbers), buttock lines (indicated by "BL"), and water lines (indicated by "WL"), were drawn on the model in order to have a reference grid with which to determine flow direction and location (See Figures 5 and 6.

EXPERIMENTAL PROCEDURE

All of the experiments contained in this report were conducted in the Circulating Water Channel (CWC) at DTNSRDC. The test section of the CWC is 10.0 meters long, 6.4 meters wide, and has a maximum water depth of 2.74 meters. Additional information describing the water channel is provided in reference 2.

Observations were made of the flow around the hull and the principal appendages with the model ballasted to the design displacement condition of 1260 tons (1280 tonnes), at model speeds of 3.44 knots and 4.41 knots, corresponding to the full scale design speed of 11.0 knots and the full scale maximum speed of 14.1 knots, respectively. (See Reference 3.) The flow from the transom was also observed for three displacements and over a range of speeds from 5.0 to 14.1 knots, full scale. The three displacements at which the transom flow was observed were 1090 tons (1107 tonnes), 1260 tons (1280 tonnes), and 1440 tons (1460 tonnes), with corresponding drafts of 9.5 feet (2.9 meters), 10.5 feet (3.2 meters), and 11.5 feet (3.5 meters), respectively. The propeller rotational speed was set to simulate the free route condition corresponding to operating in smooth, deep, salt water with a temperature of 59 degrees Fahrenheit (15 degrees Celsius). The model was free to trim, heave and roll but restrained in yaw, sway and surge.

Flow direction was indicated by two-inch (5.08 cm) long wool tufts either mounted to the surface of the model, or tied to the head of a pin located approximately 1.0 inch (2.54 cm) from the surface of the model. All surface-mounted tufts were black, and all pin-mounted tufts were red. Between stations 15 through 20 tufts were mounted at the intersection of every station and half station with the 4, 8, 12, 16, and 20 foot (1.22, 2.44, 3.66, 4.88, and 6.1 m) buttock lines, and the 8, 10, and 12 foot (2.44, 3.05, and 3.66 m) water lines. Between stations 1 through 8 tufts were mounted at the intersections of the full and half stations with the 2, 4, 6, 8, 10, and 12 foot (0.61, 1.22, 1.83, 2.44, 3.05, and 3.66 m) water lines. Port and starboard tuft locations were symmetrical with respect to the ship centerline. Port and starboard tufts were different in that the location which had a pin-mounted red tuft on one side of the model would have a surface-mounted black tuft at the corresponding location on the other side. The bilge keel flow was defined by surface mounted tufts on the outboard edge of the bilge keel and pinned tufts located on lines approximately 10 inches (25.4 cm) above and below the intersection of the keel and the hull).

RESULTS OF FLOW OBSERVATIONS

FLOW AROUND BOW THRUSTERS AND TORPEDO TUBES

There are a total of six bow thruster ports on the ship. The four intake ports, (two on each side), are located near stations 3 and 3.5, on the ship's keel. The two exit ports are located near station 3 on the 12 foot water line. The two forward facing torpedo tubes are the oval shaped openings near station 2 on the 3 foot water line. Figure 5 presents a photograph of the bow of Model 5442 for reference.

The direction of the flow in the vicinity of the thruster ports and torpedo tube openings was determined by averaging the downwash angle of the tufts nearest the port in consideration. The downwash angle is defined as positive clockwise with zero degrees parallel to the at-rest waterplane. For the 11.0 knot ship speed, the average downwash angle for the bow thruster intakes was 10.0 degrees, and for the torpedo tube openings was 15.0 degrees, as can be seen in Figures 8 and 9. At the design displacement the bow thruster exits are above the

waterline and can not be seen in this view. The average downwash angles for the 14.1 knot ship speed were 9.0 degrees for the thruster intakes, and 17.0 degrees for the torpedo tube openings, as seen in Figures 10 and 11.

BILGE KEEL ALIGNMENT

The bilge keels on Model 5442 were placed in their present position by the University of Michigan. Figure 12 is a photograph of the bilge keel taken at the 11.0 knot ship speed during the flow visualization experiments. The positioning of the tufts in the flow stream confirm the adequacy of the bilge keel alignment. Note that all the surface mounted black tufts are streaming along the outboard edge of the bilge keel, and all the pin mounted red tufts are flowing in the direction of the present location of the bilge keel. The bilge keel alignment was also satisfactory at the maximum speed of 14.1 knots, as shown in Figure 13.

RUDDER FLOW SEPARATION AND VENTILATION

In order to determine the minimum rudder angles at which flow separation and ventilation inception occurs, the model was tested at the design displacement at full scale speeds of 11.0 and 14.1 knots. At each of the speeds the rudder angle was changed from 0 degrees to its maximum angle of 45 degrees, in both the port and starboard directions, and observed for signs of separation or ventilation.

Figure 14 shows the model at the 11.0 knot ship speed with the rudder at 0 degrees with fully attached flow. At a rudder angle of 30 degrees the rudders showed very slight separation near the junction of the rudder and the rudder stool. In Figure 15 the rudders are deflected to 33 degrees port and flow separation is evident. At the 11.0 knot design speed no signs of flow ventilation were observed for any rudder deflection up to the 45 degree maximum angle.

For the 14.1 knot maximum speed the rudder again shows fully attached flow at the 0 degree rudder angle, as shown in Figure 16. Figure 17 shows separated flow on the rudders when at an angle of 30 degrees starboard. Partial rudder

ventilation was observed (rudder ventilation would periodically build up slowly and then quickly subside) at an angle of 40 degrees when deflected in both the port and starboard directions. At a rudder angle of 45 degrees to starboard, as shown in Figure 18, the port rudder became fully ventilated. In the case of a 45 degree rudder deflection to port, as shown in Figure 19, the starboard rudder became fully ventilated.

TRANSOM FLOW OBSERVATIONS

Observations of the above water portion of the transom indicate that at the design displacement condition the flow does not separate from the transom of the YFRT even at the maximum speed. Figure 20 is a photograph of the transom flow at the 11.0 knot design speed and design displacement. An area of "dead" water was observed at this displacement over a speed range of 5 to 10 knots. The area of stagnation extended from the centerline out to both the port and starboard 12 foot (3.66 m) buttock lines. (Stagnation was indicated by "lazy" tufts and motionless bubbles on the water surface.)

In order to determine if the flow could be made to separate cleanly from the transom, the model was ballasted to a light displacement of 1090 tons (1107 tonnes). For this displacement case the conclusions were the same as in the design case. That is, the flow did not separate from the transom even at the maximum speed, and an area of stagnation was present at the lower end of the speed range.

The observed flow, below the waterline, aft of station 15 tended to be mostly buttock flow with a small inward (toward centerline) component, except in the vicinity of the skeg where there was all buttock flow. The flow near the intersection of the shafts and the hull was deflected noticeably by the shafts. No flow separation was observed aft of Station 15.

DISCUSSION

Froude scaling has been used throughout these flow visualization tests to determine the relationship between the full scale and model speeds. While

Froude scaled speeds do represent wave making and free surface effects correctly, they may not represent ventilation inception correctly. Therefore, the rudder angles reported herein for ventilation and flow separation observed on the model may not occur on the full scale ship at the same rudder angle or Froude scaled speed. However, the effects of ventilation on the model are generally considered to be worse than on the full scale ship due to the scale effects. Therefore, rudder ventilation will generally occur on the full scale ship at higher rudder angles.

Observations of the bow torpedo tube openings showed that there was an area of unstable turbulent flow behind the opening. It is therefore suggested that a redesign of the torpedo tube opening should be considered. One possible redesign would be to elongate the opening in the direction of the downwash angle in order to fair it into the flow. This procedure was proven to be successful in model tests on a Coast and Geodetic Survey Ship conducted by E.N. Hubble, (Reference 4).

CONCLUSIONS

At the 11.0 knot design ship speed, the average downwash angle over the bow thruster intake ports was 10.0 degrees, and the average downwash angle over the torpedo tube openings was 15.0 degrees. The average downwash angles at the 14.1 knot maximum speed were 9.0 degrees and 17.0 degrees for the bow thruster and torpedo tubes, respectively.

The bilge keel alignment was satisfactory at both the design speed of 11.0 knots and the maximum speed of 14.1 knots.

At the 11.0 design speed no rudder ventilation occured up to the 45 degree maximum rudder deflection. Separation of flow around the rudder was observed at a rudder angle of 33 degrees when deflected in both the port and starboard directions.

At the 14.1 knot maximum speed incipient rudder ventilation occured at both a port and starboard rudder deflection of 40 degrees. When the rudder angle was increased to 45 degrees to starboard, the port rudder became fully ventilated. At a rudder angle of 45 degrees to port, the starboard rudder became fully ventilated. At this speed, rudder flow separation occured at a rudder angle of 30 degrees.

At the design displacement condition of 1260 tons (1280 tonnes), even keel, the transom remained wetted up to the 14.1 knot maximum speed.

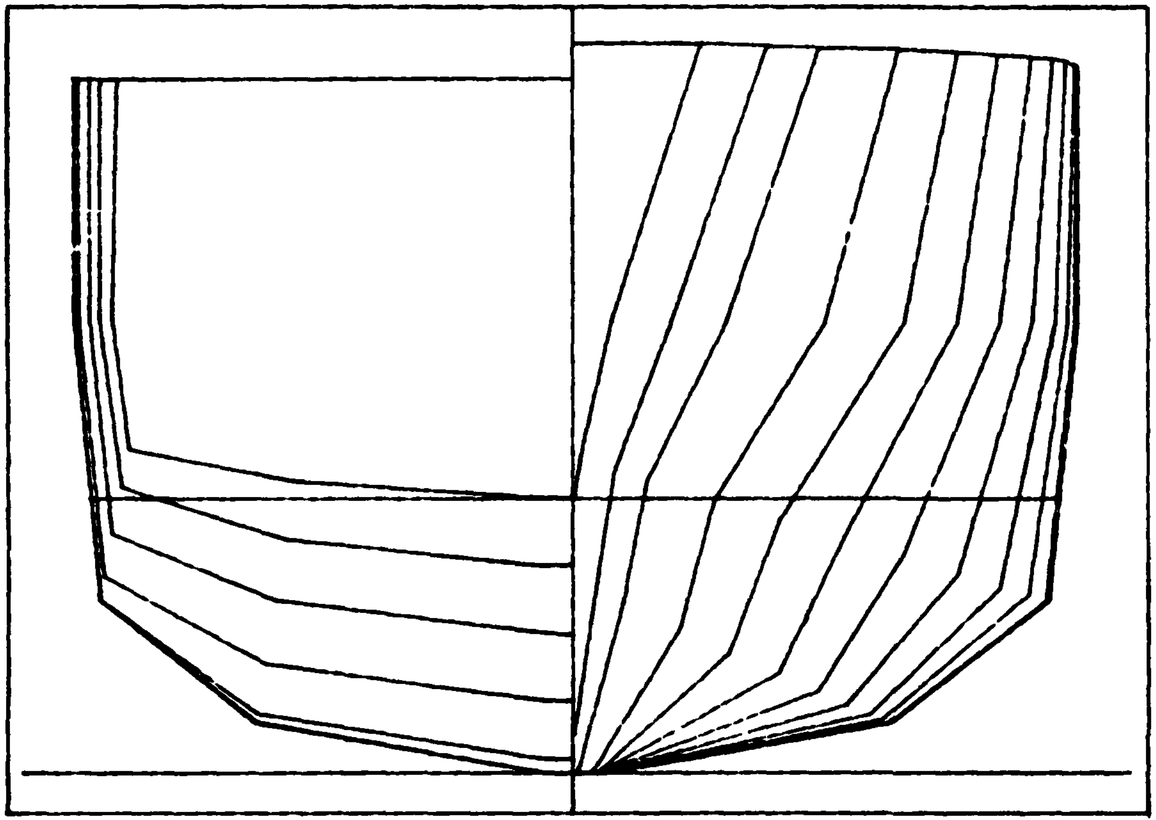
REFERENCES

1. University of Michigan, "Weapons Range Support Craft (YFRT) Preliminary Design", NKF Engineering Deliverable 8100-086/48A, (Jan. 1985).

2. Vincent, M. DaL., "The U.S. Navy's Center of Excellence for Ship Research", NSRDC Report 3039, (Nov. 1971).

3. Cusanelli, D.S., "Stock Propeller Powering Prediction and Propeller Disk Wake Survey for the Weapons Range Support Craft YFRT as Represented by Model 5442", DTNSRDC Ship Performance Department Report SPD-1140-01, (May 1985)

4. Hubble, E.N., "Power Predictions for a Coast and Geodetic Survey Ship, Model 4908", DTMB Hydromechanics Laboratory Research and Development Report No. 1624, (March 1962).



NONDIMENSIONAL COEFFICIENTS

C_B	= 0.551	L_{WL}/B_X	= 5.157
C_P	= 0.690	B_X/T_X	= 3.654
C_{PF}	= 0.680	A_T/A_X	= 0.000
C_{PA}	= 0.700	B_T/B_X	= 0.000
C_{PE}	= 0.636	T_T/T_X	= 0.000
C_{PR}	= 0.565	A_B/A_X	= 0.000
C_X	= 0.798	L_E/L_{WL}	= 1.112
C_{WP}	= 0.788	L_P/L_{WL}	= 0.404
C_{WPF}	= 0.645	L_R/L_{WL}	= 0.504
C_{WPA}	= 0.930	FB/L_{WL}	= 0.530
C_{VP}	= 0.690	FF/L_{WL}	= 0.504
C_{VPF}	= 0.743	C_∇	= 0.00567
C_{VPA}	= 0.660	S	= 0.310
C_S	= 2.664	M	= 5.600
f	= 0.000	$\Delta/(.01L_{WL})^3$	= 162.03

i_E = 15.784 DEGREES

i_B = 14.171 DEGREES

i_R = 14.940 DEGREES

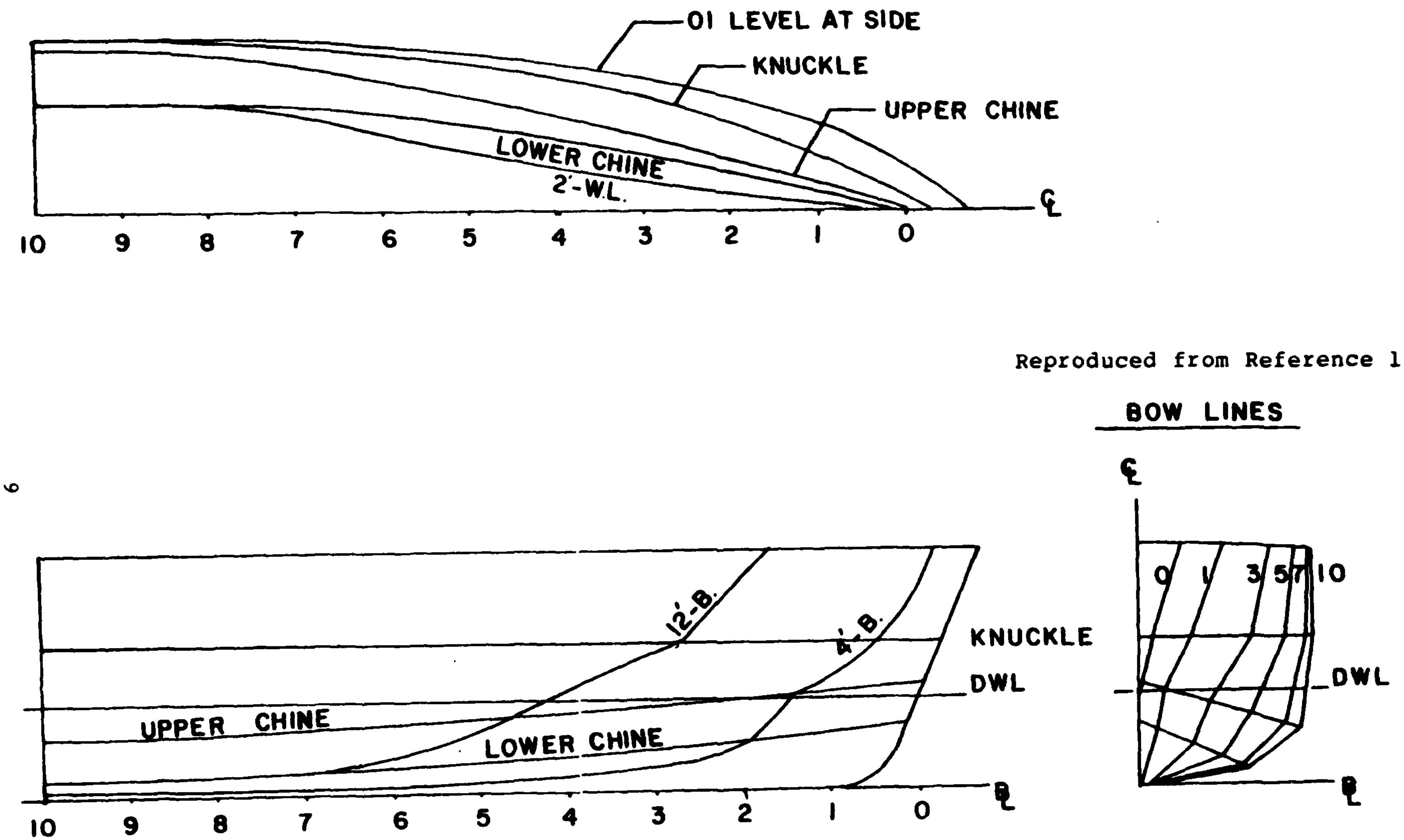
MODEL SCALE DATA

LENGTH (L_{PP}) =	1.257 M	(4.13 FT)
LENGTH (L_{WL}) =	1.256 M	(4.12 FT)
BEAM (B_X) =	0.244 M	(0.80 FT)
DRAFT (T_X) =	0.067 M	(0.22 FT)
DISPLACEMENT =	0.011 t	(25 LBS)
WETTED SURFACE =	0.317 SQ METERS	
=	3.409 SQ FEET	
SCALE RATIO =	48.000	

PRINCIPAL DIMENSIONS

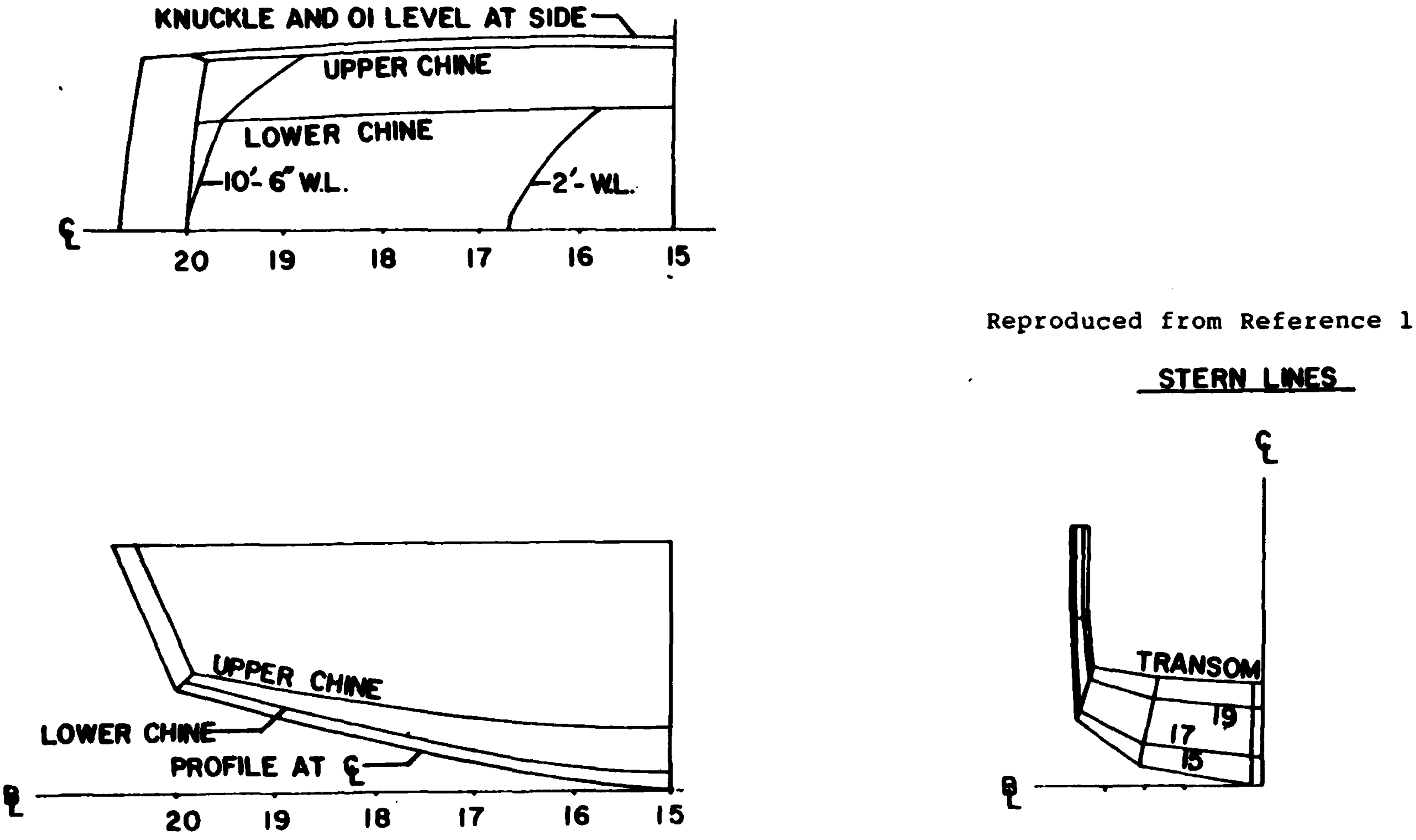
LENGTH (L_{PP}) = 198.00 FEET	LENGTH (L_{PP}) = 60.35 METERS
LENGTH (L_{WL}) = 197.87 FEET	LENGTH (L_{WL}) = 60.31 METERS
BEAM (B_X) = 38.37 FEET	BEAM (B_X) = 11.70 METERS
DRAFT (T_X) = 10.50 FEET	DRAFT (T_X) = 3.20 METERS
TRIM = 0.00 FEET (+ BOW)	TRIM = 0.00 METERS (+ BOW)
DISPLACEMENT = 1260 L TONS	DISPLACEMENT = 1280 t
WETTED SURFACE = 7854 SQ FT	WETTED SURFACE = 729.6 SQ M

1. - Body Plan and Principal Dimensions of YFRT at Design Displacement

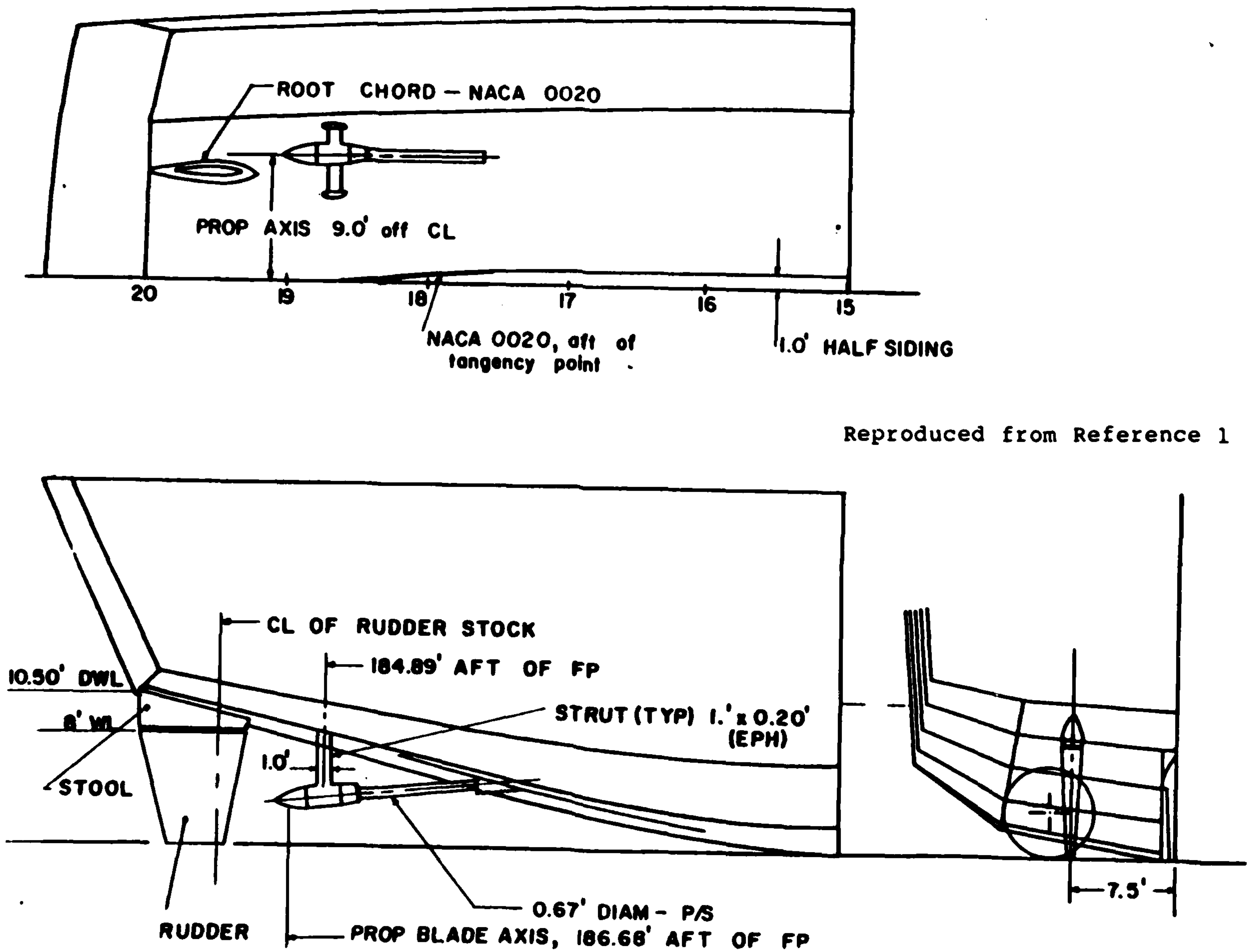


Reproduced from Reference 1

2. - Bow Lines of YFRT as Represented by Model 5442

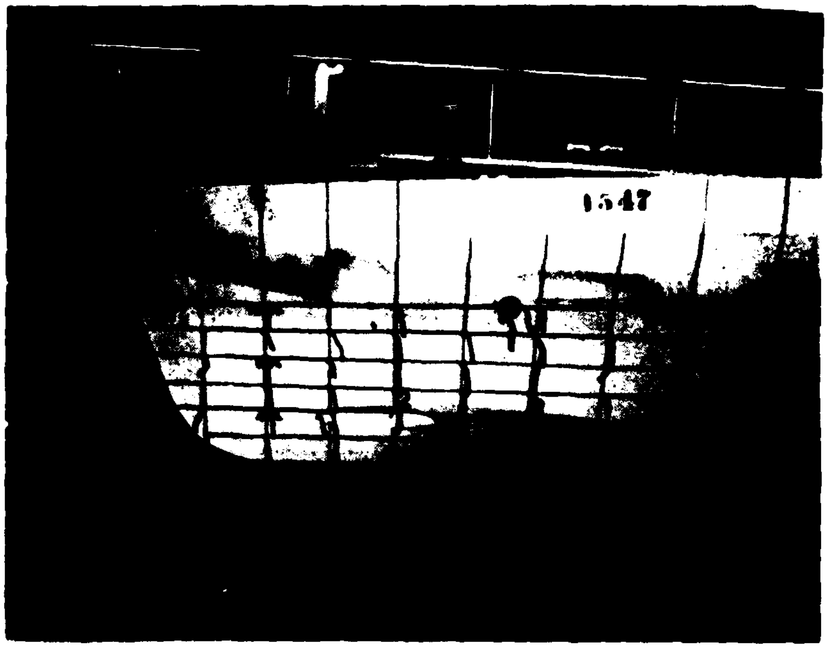


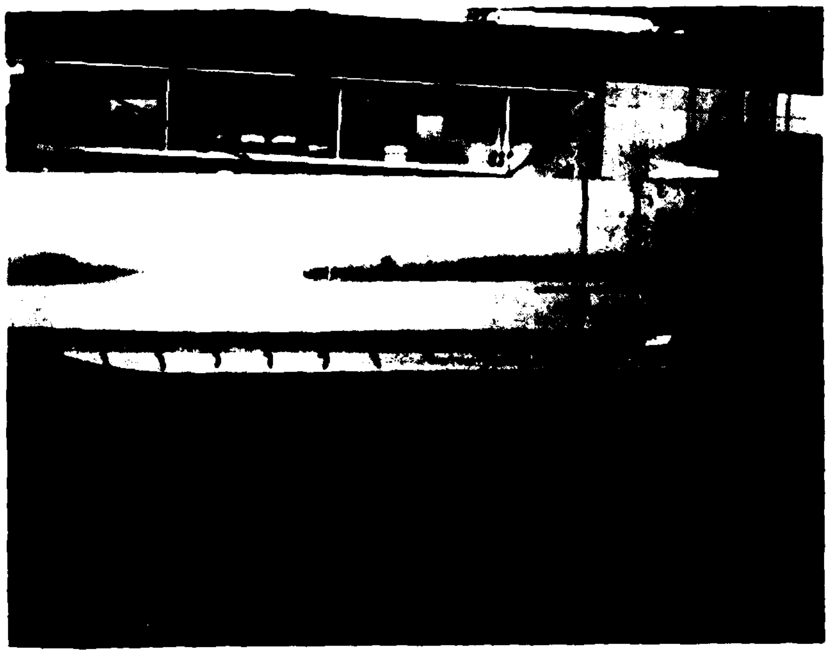
3. - Stern Lines of YFRT as Represented by Model 5442



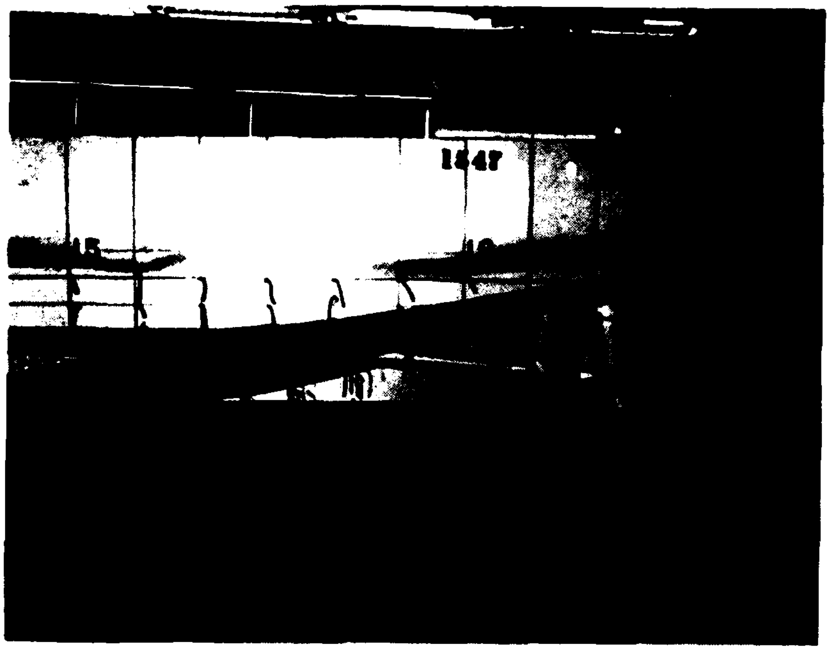
Reproduced from Reference 1

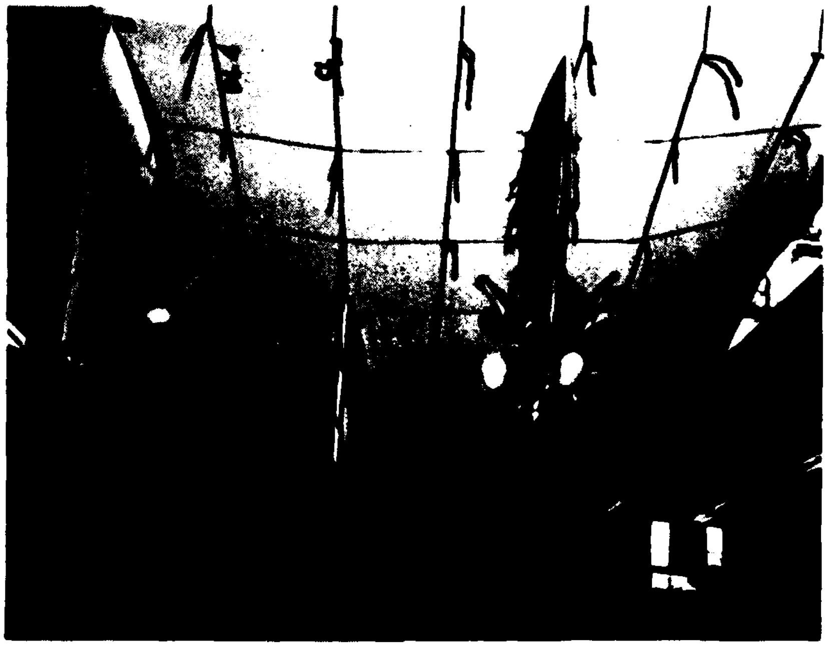
4. - Detailed Drawing of Stern Appendages of YFRT as Represented by Model 5442



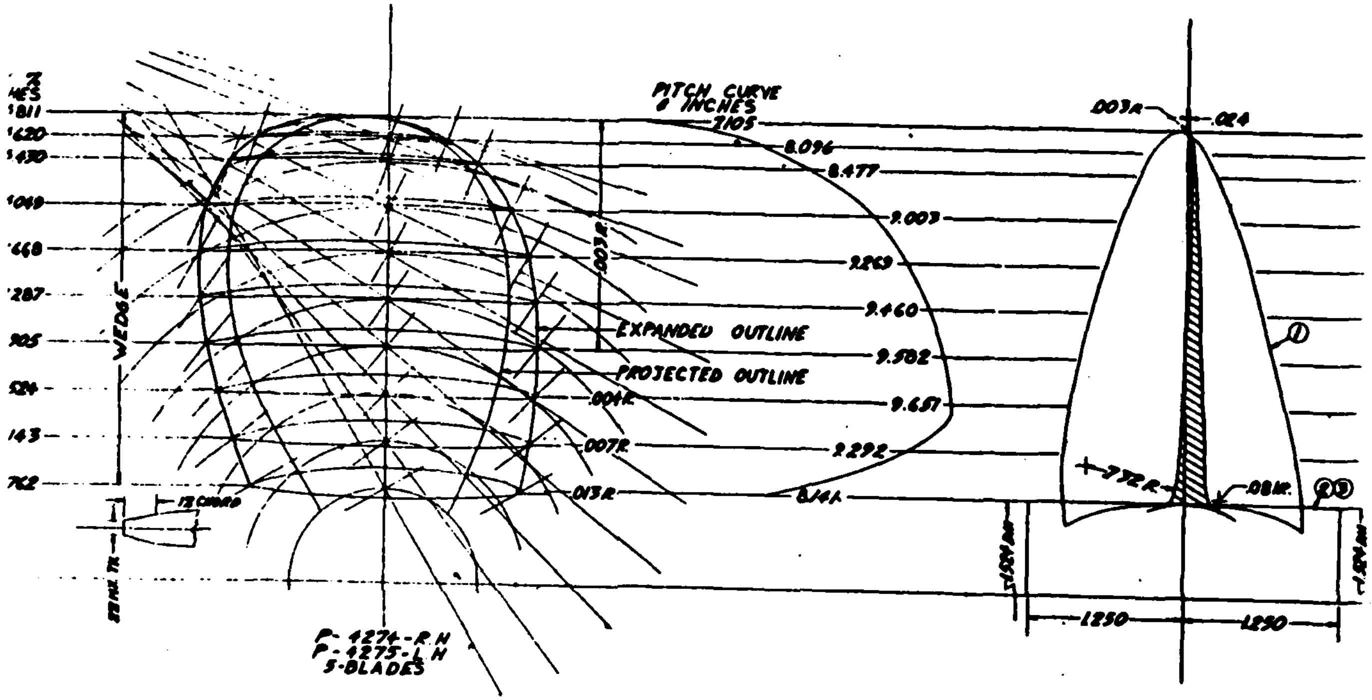


5 - Photographs of Bow and Bilge Keel of Model 5442 as Equipped for the Flow Visualization Experiments



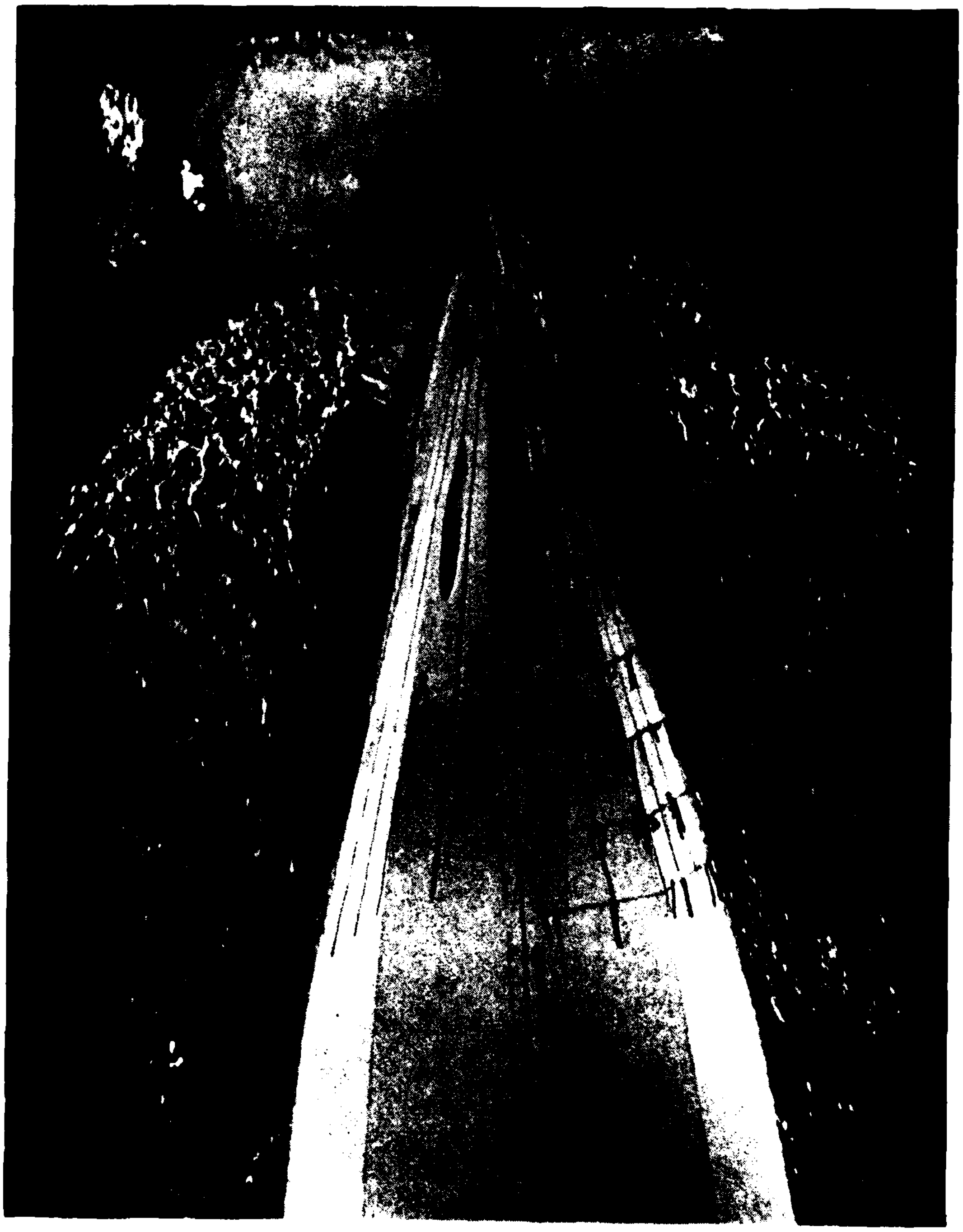


6 - Photographs of Stern of Model 5442 as Equipped for the Flow Visualization Experiments



7. - Propeller Drawing of DTNSRDC Propeller Number 4274

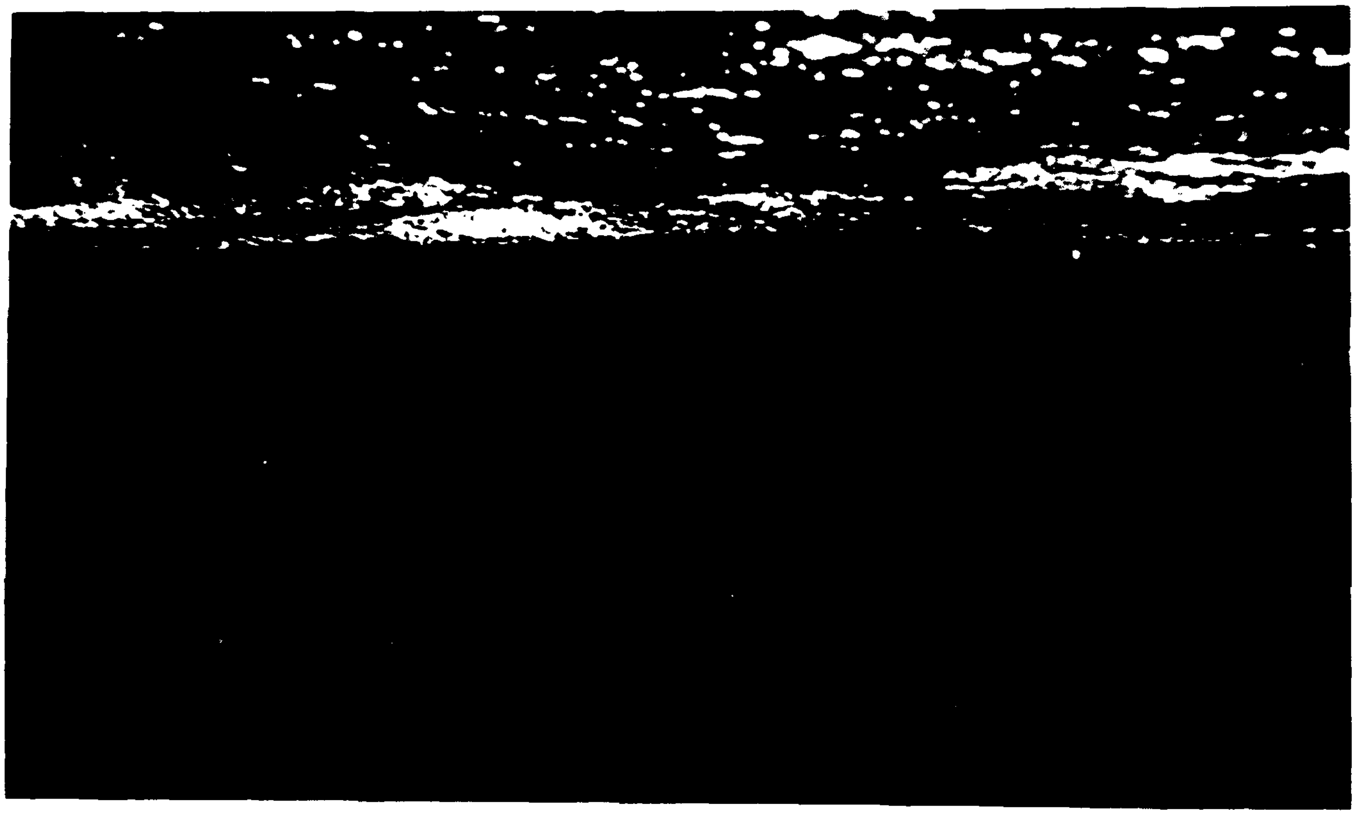
8. - Profile View Showing Flow Near Bow Thrusters and Torpedo Tubes at 11.0 Knot Ship Speed



'. - Bottom View Showing Flow Near Bow Thrus'ers and Torpedo Tubes at 11.0 Knot Ship Speed

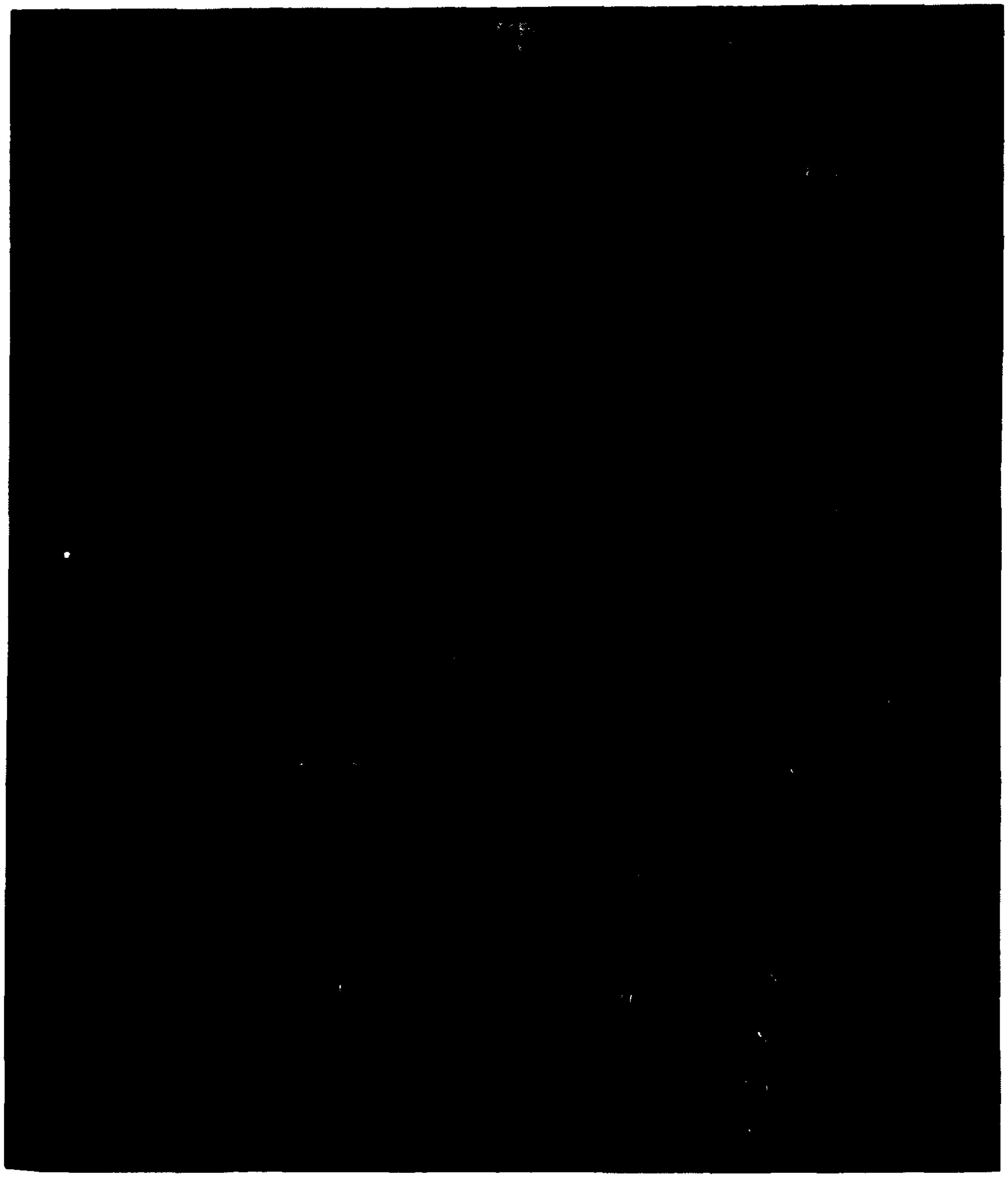
10.- Profile View Showing Flow Near Bow Thrusters and Torpedo Tubes at 14.1 Knot Ship Speed

11.- Bottom View Showing Flow Near Bow Thrusters and Torpedo Tubes at 14.1 Knot Ship Speed

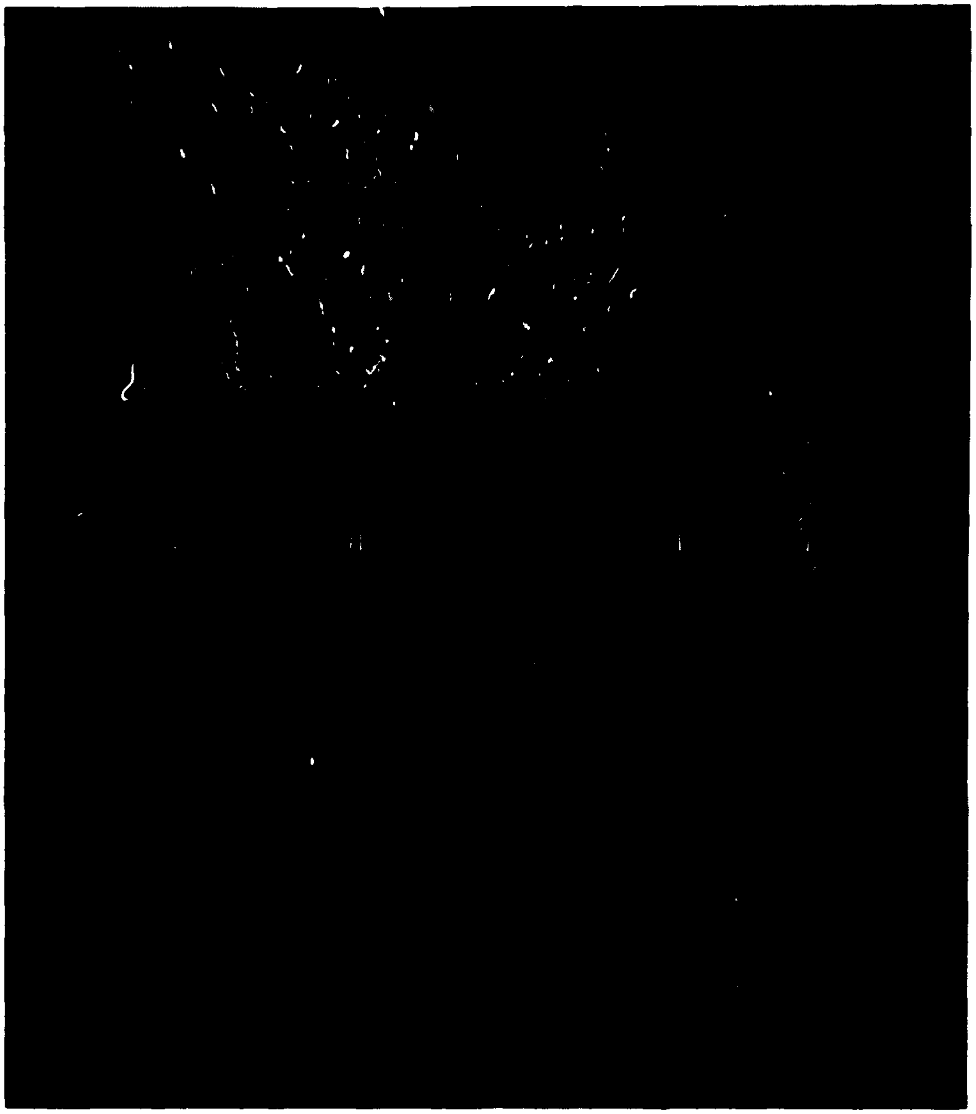


12.- Photograph of Bilge Keel Alignment Check at 11.0 Knot Ship Speed

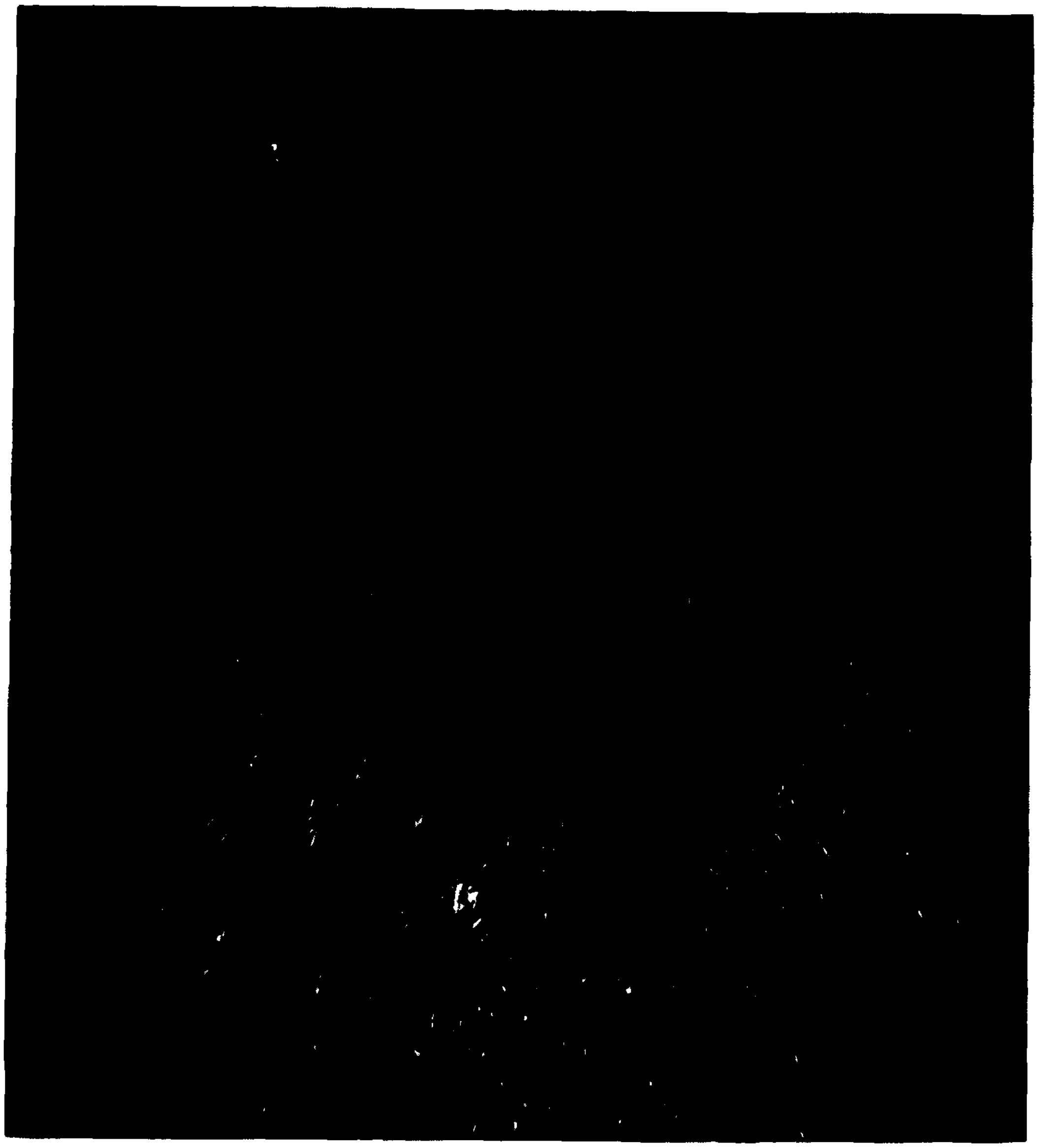
13.- Photograph of Bilge Keel Alignment Check at 14.1 Knot Ship Speed



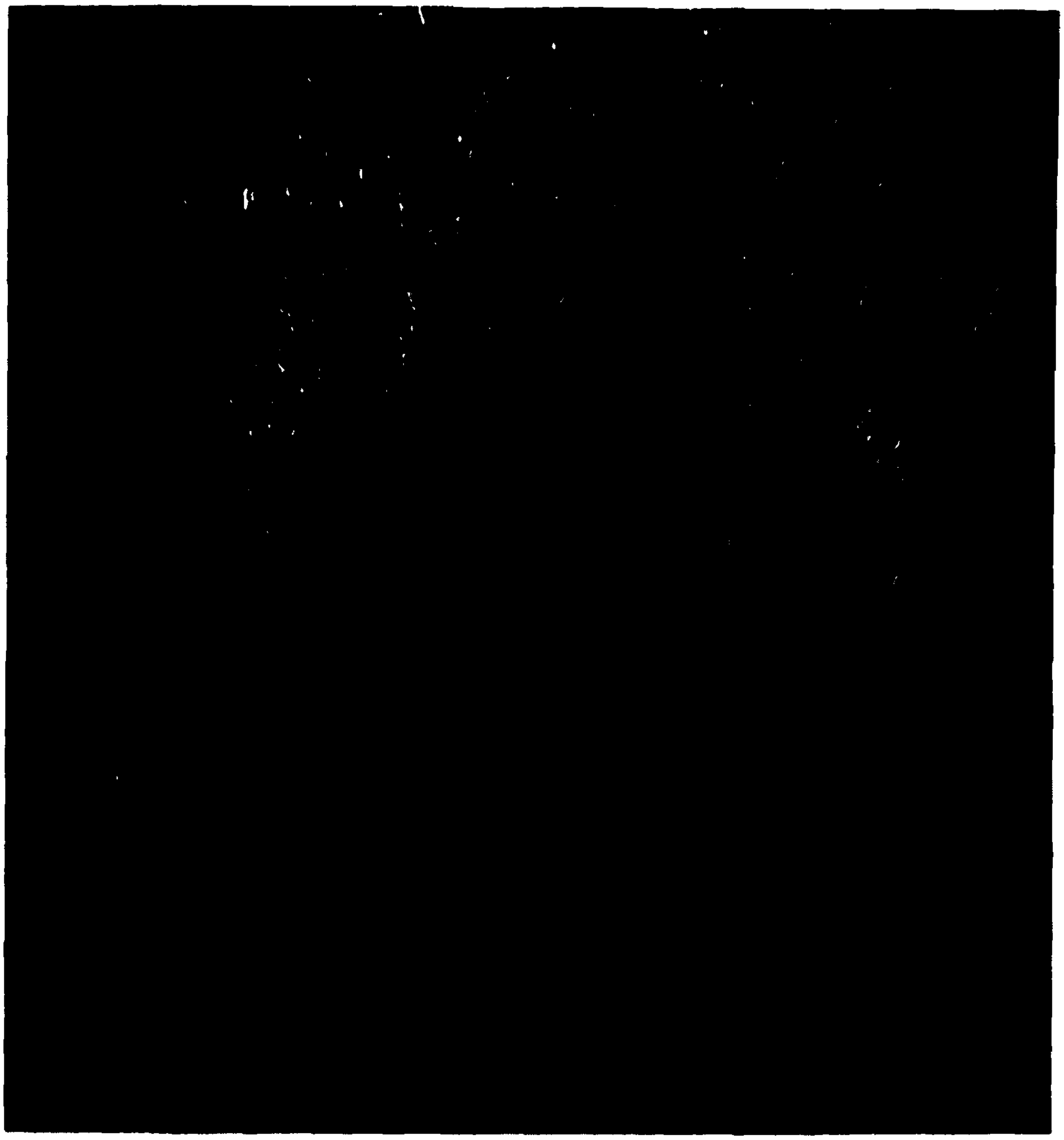
14.- Bottom View of Stern at 11.0 Knot Ship Speed, 0 Degree Rudder Angle



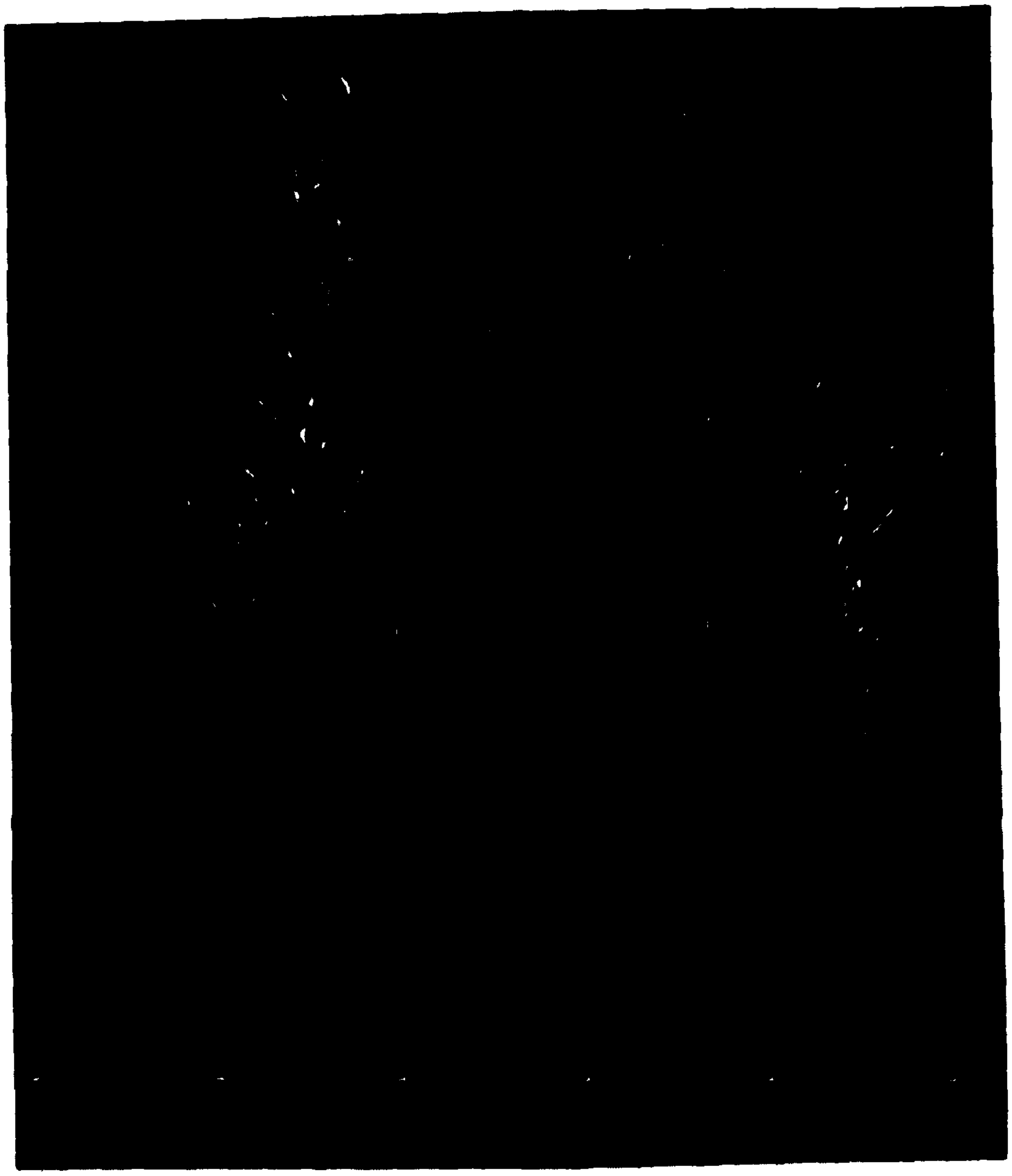
15.- Bottom View of Stern at 11.0 Knot Ship Speed, 33 Degrees to Port Rudder Angle



16.- Bottom View of Stern at 14.1 Knot Ship Speed, 0 Degree Rudder Angle

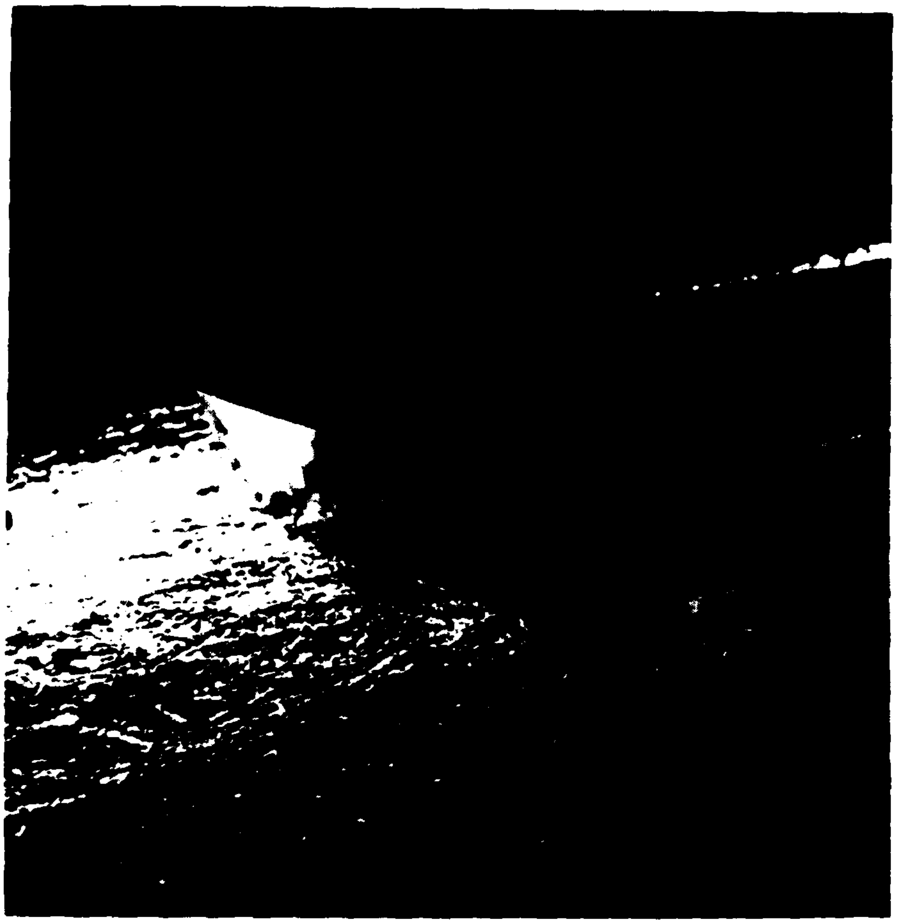


17.- Bottom View of Stern at 14.1 Knot Ship Speed, 30 Degrees Starboard Rudder Angle



18.- Bottom View of Stern at 14.1 Knot Ship Speed, 45 Degrees Starboard Rudder Angle

19.- Bottom View of Stern at 14.1 Knot Ship Speed, 45 Degrees Port Rudder Angle



20.- Above Water View of Transom at 11.0 Knot Ship Speed, Design Displacement

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